98-1-311IP PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Newell. Et al.

Serial No.: 09/413,923 Art Unit: 2879

Filed: 10/07/1999 Examiner: Williams, J.

For: MERCURY-FREE METAL HALIDE ARC LAMPS

Commissioner for Patents
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Sir:

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William H. McNeill

APPEAL BRIEF UNDER 37 C.F.R. 1.192

Applicants hereby present to the Board Of Appeals their Brief in support of their Appeal from the decision of the Primary Examiner finally rejecting Claims 1, 3 and 5, in the above-identified application. The Fee has previously been paid.

Three copies of the Brief are enclosed.

REAL PARTY IN INTEREST

The real party in interest in this appeal is OSRAM SYLVANIA Inc., a wholly owned subsidiary of Siemens AG.

RELATED APPEALS AND INTERFERENCES

There are no appeals or interferences pending which are related to the instant appeal.

STATUS OF THE CLAIMS

Claims 2 and 4 have been cancelled.

No claims have been allowed.

Claims 1, 3 and 5 have been rejected.

Claims 1, 3 and 5 are appealed. These claims are delineated in the Appendix attached hereto.

STATUS OF AMENDMENTS

All amendments have been entered.

A previously filed Brief resulted in the Final Rejection being withdrawn and a new Office Action issued. However, since the claims are not to be changed and have been twice rejected, Applicants have elected to proceed directly to appeal.

SUMMARY OF INVENTION

The invention is a mercury-free metal halide lamp having an aspect ratio, i.e., the arc length divided by the bore diameter, of greater than 5, (Figs. 2a, 2b and 3) a buffer gas of xenon, argon or krypton and a selection of metal iodides including sodium, scandium, lithium and cesium. (Specification, page 3, lines 21-30). Additionally, the arc chamber or vessel is comprised of fused silica having pinched-sealed ends. (Specification, page 5, lines 7-10).

ISSUES

Whether Claims 1, 3 and 5 are patentable under 35 U.S.C. §103(a) over the teachings of Dakin et al. (4,757,236) in view of Ramaiah (4,866,342), newly cited.

GROUPING OF CLAIMS

The claims will stand or fall together.

ARGUMENTS

35 U.S.C. 103

Claims 1, 3 and 5, all of the remaining claims in this application, are rejected under 35 U.S.C. §103(a) as being obvious in view of the combination of Dakin et al. and Ramaiah. The rejection is in error and its reversal is respectfully requested.

Dakin et al., while mentioning the existence of metal halide lamps generally and even characterizing their invention as a metal halide lamp, relates and teaches only a high pressure sodium iodide lamp which may or may not include one other metal halide (see Dakin et al., col. 1, line 68 through col. 2, line 1; col. 2, lines 14-16; and col. 3, lines 37-39). At col. 4, lines 65-68, Dakin et al. state that other metal halides can be added to the fill to improve color; however, no other materials are mentioned. At the end of their list of Examples, at col. 4, lines 59 et seq., Dakin et al. state:

> "The foregoing describes a high pressure sodium iodide arc lamp and a fill for such lamp wherein xenon is chosen as the buffer gas rather than mercury, as in conventional arc lamps."

Applicants respectfully submit that the Examiner is either ignorant of, or refusing to recognize, the fact that different classes of high intensity discharge lamps exist and that these classes have distinct definitions as applied by those skilled in the art.

To support this allegation, attached hereto as Exhibit A is a copy of specific pages from the IESNA Lighting Handbook, the "Bible" of the lighting industry. "IESNA" refers to the Illuminating Engineering Society of North America.

Reference to "Page 3" of the exhibit (references to page numbers herein refer to the page numbers added at the bottom of the pages of the exhibit) reveals the definition of the generic term "high pressure discharge devices" as including mercury lamps, high pressure sodium lamps and metal halide lamps. This definition is repeated at page 4, second column. Each of these lamps produce characteristic lines of radiant energy by exciting different materials; for example, mercury vapor lamps produce light by exciting mercury atoms; high pressure sodium lamps produce light by exciting sodium atoms; and metal halide lamps produce light by exciting several different atoms and molecules, primarily sodium, scandium, thulium, holmium and dysprosium. Note that even though a metal halide lamp contains sodium, it is not considered to be a high pressure sodium lamp.

Further, more specific conditions for metal halide lamps are provided at page 6 of the exhibit. Note that metal halide lamps are distinguished from the older mercury vapor lamps by the addition of various other metal halides plus ***mercury*** and argon. (Emphasis added).

Further, more specific conditions of high pressure sodium lamps will be found at page 9 of the exhibit, wherein it is clearly stated that such lamps employ polycrystalline alumina arc tubes, which material is resistant to sodium attack at high temperatures and pressures.

As a still further assertion of the differences between these types of lamps as understood in the art, see page 10 of the exhibit wherein the designations of the lamps as applied and administered by ANSI, and followed by the industry, are displayed.

With the above descriptions in mind, Applicants again refer to the description of their invention as being a mercury-free ***metal halide lamp*** having a specific aspect ratio.

Claim 1, which is the broadest claim, actually recites only a mercury-free arc vessel, of a specific material (fused silica), an aspect ratio of less than 5, and the fill of materials that is common to a ***metal halide lamp***.

Referring now to the references applied in the rejection, clearly, even Dakin et al. recognize that they are disclosing a high-pressure sodium lamp and not a metal halide lamp, as that term is generally employed in the art. See, for example, the previously cited Russell patent, which does relate to what the industry considers a metal halide lamp. While Dakin et al. make occasional broadening disclosures of the addition of other metal halides and, at the referenced Col. 2, lines 43-47, to the use of fused quartz as an arc tube vessel material, it is apparent that the arc tube material is polycrystalline alumina, since the art is well aware that only that material will work properly. (Again, see the exhibit, page 9).

The Examiner states in the Final Rejection, at page 2, 4th paragraph, that Dakin et al. show a metal halide lamp having pinched-sealed ends. This statement is incorrect, as the Examiner recognizes at the top of page 3 of the Office Action, wherein it is stated that Dakin et al. do not discuss pinch seals at all. Fig. 3 of Dakin et al. clearly shows an arc tube comprised of polycrystalline alumina, which is why the end caps are necessary. To remedy this deficiency of a lack of pinch-seal teaching, Ramaiah is cited.

Ramaiah et al. does relate to a metal halide lamp and does include pinch seals; however, Ramaiah et al. also discloses a more-or-less conventional metal halide that includes mercury. See Ramaiah et al., col. 2, line 18.

The Examiner states that Dakin et al. disclose a fill selected from the group consisting of sodium, scandium, lithium or cesium. This statement also is in error. The only other halide mentioned in Dakin et al. is scandium iodide and it appears only in reference to Dakin et al. Example IV.

Clearly, the only suggestion for the instant claimed ***metal halide lamp*** with its unique arc tube configuration, specific fill and mercury-free environment comes from the instant application and this teaching is not available to the Examiner.

> "In determining obviousness of claimed apparatus under 35 U.S.C. 103, it is improper to modify reference in light of applicant's own disclosure." **Ex parte Camarata**; 151 USPQ 739; PO Bd of App; Mar. 1 and May 17, 1966.
>
> "Fact that disclosures of references can be combined does not make combination obvious unless the art also contains something to suggest desirability of combination." **In re Imperato**; 179 USPQ 730; CCPA; Nov. 15, 1973.

In response to a previous Office Action the instant claims were amended to clarify the invention and to advance prosecution by adding the limitations that the arc vessel is constructed of fused silica and has pinch-sealed ends. The Examiner dismisses these additions as obvious design choices, apparently because applicants' disclosure fails to state that these features solve a stated problem outside the scope of the art.

This conclusion of the Examiner's is incorrect on two grounds.

First, it is pointed out that the art does not show ***metal halide arc lamps*** containing more than two halides and ***with aspect ratios greater than 5***, with or without pinched-seal ends; therefore, the art does not evidence such a choice.

> "It is quite clear from the art cited that it does not show the invention nor suggest the same. The examiner's rejection is based on the assertion that it is a mere matter of choice...
>
> However, applicant has a new means to accomplish the result..." **Ex parte Krantz;** 61 USPQ 238; Patent Office Board of Appeals; Oct. 12, 1943.

And:

> "The examiner then says that these are a matter of choice. It is not a matter of choice presented by the prior art. The prior art gives only one choice; a process which will not yield these new and improved results." Ex parte Haas, Connelly, and Van Voorhis: 144 USPQ 98; Patent Office Board Of Appeals; Mar. 19, 1964.

Second, under the circumstances enumerated above it is believed to be improper for the criticality of matter added to advance prosecution to be required.

> "There is no reason for requiring showing of criticality of limitation which finds support in original disclosure, which is added to claims for purposes of advancing prosecution of application, and which is never alleged by applicant to be critical; if applicant under these circumstances narrows scope of claims, he should be entitled to do so without being required to prove criticality." In re Luvisi and Noheil; 144 USPQ 646; CCPA, Mar. 11, 1965

As to the further comments concerning Claim 5, it is pointed out that Claim 5 depends from Claim 3 and requires a lamp having an aspect ratio greater than 5, a particular fill, a particular arc vessel that has a mercury-free environment and a ballast supplying between 250 and 400 watts to operate the lamp. The Examiner's statement that Dakin et al. inherently comprise such a ballast is incorrect. All of the Examples of Dakin et al. lamps were run at 500 to 550 watts and there is no suggestion that the Dakin et al., lamps could be run at lower wattages. As noted in the instant specification at page 3, lines 1-5, lamps designed as claimed herein produce starting voltages of 40 to 50 volts. At currents of 5 to 7 amperes these lamps consumed about 250 to 400 watts, which was sufficient to raise the operating temperature of the lamps to suitable values. This feature is clearly lacking in Dakin et al. and there is no suggestion in Dakin et al. that their lamps would operate at such levels.

None of the missing teachings of Dakin et al. are supplied by Ramaiah et al. since the latter clearly requires mercury for the lamp to operate. The lack of specific teachings for the construction of a mercury-free metal halide lamp, in spite of the fact that the industry has long sought such a lamp (see specification, page 2, lines 11-14) is a clear indication that only the instant disclosure provides this meaningful invention.

Thus, Dakin et al. teach a high pressure sodium lamp that is mercury-free. Applicants teach a metal halide lamp that is mercury-free and has a specific aspect ratio. To supply the deficiency of lack of teaching relative to metal halide lamps in Dakin et al., the Examiner cites Ramaiah et al. to show that metal halide lamps are known and proposes that it would be obvious to one skilled in the art to make this combination, in spite of the fact that Ramaiah et al. teach a metal halide lamp that requires mercury. It is respectfully pointed out that this mercury-free metal halide concept comes only from the instant disclosure and such teaching is not available to the Examiner.

The most that can be said from the combination proposed by the Examiner is that there might be present an invitation to experiment; however, a rejection under 35 U.S.C. 103 needs more than that.

CONCLUSION

According, it is believed that error was made in the rejection of the pending claims under 35 U.S.C. §103(a) and reversal of the rejections and allowance of the claims is respectfully solicited.

Respectfully submitted,

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APPENDIX

1. A mercury-free, arc vessel constructed of fused silica having a pinched-seal at each end and having an aspect ratio greater than 5 and containing a fill comprised of iodides selected from the group consisting essentially of sodium, scandium, lithium, cesium and a buffer gas selected from the group consisting of xenon, argon and krypton.

3. A mercury-free, metal halide lamp comprising; an outer envelope containing an atmosphere selected from the group consisting of vacuum and nitrogen; and an arc discharge vessel constructed of fused silica having a pinched-seal at each end and mounted therein; said vessel having an aspect ratio greater than 5 and containing a fill comprised of iodides selected from the group consisting of sodium, scandium, lithium or cesium and a buffer gas of from about 50 torr to 500 torr selected from the group consisting of xenon, argon and krypton.

5. The lamp of Claim 3 wherein said lamp is operated by a ballast supplying power to operate said lamp between approximately 250 watts and 400 watts.

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LIGHTING HANDBOOK

REFERENCE & APPLICATION

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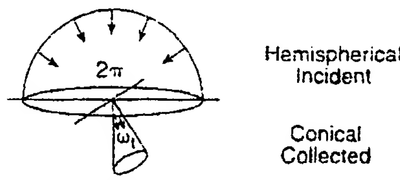
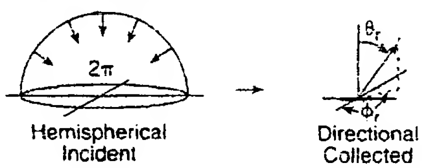
hemispherical-conical transmittance, $\tau(2\pi; \omega_t)$ the ratio of transmitted flux collected over a conical solid angle to the incident flux from the entire hemisphere.

Note The direction and extent of the cone must be specified.



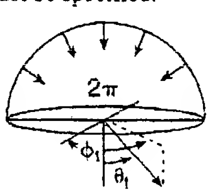
hemispherical-directional reflectance, $\rho(2\pi; \theta_r, \phi_r)$ the ratio of reflected flux collected over an element of solid angle surrounding the given direction to the incident flux from the entire hemisphere.

Note The direction of collection and the size of the solid angle element must be specified.



hemispherical-directional transmittance, $\tau(2\pi; \theta_t, \phi_t)$ the ratio of transmitted flux collected over an element of solid angle surrounding the given direction to the incident flux from the entire hemisphere.

Note The direction of collection and size of the solid angle element must be specified.



hemispherical reflectance the ratio of all of the flux leaving a surface or medium by reflection to the incident flux. The use of this term is deprecated. See *hemispherical transmittance*.

hemispherical transmittance the ratio of the transmitted flux leaving a surface or medium to the incident flux. The use of this term is deprecated.

high-bay lighting interior lighting where the roof trusses or ceiling height is greater than approximately 7.6 m (25 ft) above the floor.

high-intensity discharge (HID) lamp an electric-discharge lamp in which the light-producing arc is stabilized by bulb wall temperature, and the arc tube has a bulb wall loading in excess of 3 W/cm^2. HID lamps include groups of lamps known as mercury, metal halide, and high-pressure sodium.

high-key lighting a type of lighting that, applied to a scene, results in a picture having gradations from middle gray to white with comparatively limited areas of dark gray and black. Also, intense, overall illumination. In motion pictures, high-level accent lighting with strong contrast (dark deep shadows with little or no middle gray). See *low-key lighting*.

high-mast lighting illumination of a large area by means of a group of luminaires that are designed to be mounted in fixed orientation at the top of a high mast, generally 20 m (65 ft) or higher.

high-pressure sodium (HPS) lamp a high-intensity discharge (HID) lamp in which light is produced by radiation from sodium vapor operating at a partial pressure of about 1.33×10^4 Pa (100 Torr). Includes clear and diffuse-coated lamps.

horizontal exit† an escape route from one building to an area of refuge in another building on approximately the same level. It also is an escape route through or around a fire barrier to an area of refuge on approximately the same level in the same building.

horizontal plane of a searchlight the plane that is perpendicular to the vertical plane through the axis of the searchlight drum and in which the train lies.

hot-cathode lamp an electric-discharge lamp whose mode of operation is that of an arc discharge. The cathodes can be heated by the discharge or by external means.

house lights the general lighting system installed in the audience area (house) of a theatre, film or television studio, or arena.

hue of a perceived color the attribute that determines whether it is red, yellow, green, blue, or the like.

hue of a perceived light-source color† the attribute that determines whether the color is red, yellow, green, blue, or the like. See *hue of a perceived color*.

hydrargyrum medium-arc-length iodide (HMI) lamp an arc light source utilizing mercury vapor and metal halide additives to produce illumination in the 5000 to 6000 K range. Requires a ballast and ignitor system for operation.

I

ice detection light an inspection light designed to illuminate the leading edge of the aircraft wing to check for ice formation.

ideal radiator† See *blackbody*.

identification beacon an aeronautical beacon emitting a coded signal by means of which a particular point of reference can be identified.

ignitor a device, either by itself or in association with other components, that generates voltage pulses to start discharge lamps without preheating of electrodes.

illuminance, $E = d\Phi/dA$ the areal density of the luminous flux incident at a point on a surface

illuminance (footcandle or lux) meter an instrument for measuring illuminance on a plane. Instruments that accurately respond to more than one spectral distribution are color-corrected, that is, the spectral response is balanced to $V(\lambda)$ or $V'(\lambda)$. Instruments that accurately respond to more than one spatial distribution of incident flux are co-

for the dimming signal and the other two to carry the main lamp current.

Most currently available fluorescent lamp dimming systems incorporate electronic ballasts that use high-frequency (typically 20 to 50 kHz) switching of the lamp current. They are designed to be used with four-pin, rapid-start, and compact fluorescent lamps and are available for several lamp diameters and lengths. Electronic dimming ballasts generally are more efficient and less bulky than their autotransformer predecessors. Furthermore, lamp flicker can be substantially reduced with electronic dimming ballasts.

Most electronic ballasts offer energy savings approximately proportional to the reduction in light output (Figure 6-55). This is particularly true at dimmer settings above 25 to 50% luminous output. Furthermore, four-pin construction allows cathode heating when dimming. This is important since it extends lamp life and eliminates flicker when properly implemented. It is also advisable to select premium-quality knife-edge sockets rather than leaf-spring contacts. This ensures that cathode heating is reliably supplied. Finally, solid-state dimmers are substantially quieter (less humming) than their magnetic predecessors.

The performance of a fluorescent dimming system might not be satisfactory if the lamp is not correctly matched with the dimming ballast and the controller. In particular, reduced wattage, energy-saving retrofit lamps should not be used in dimming systems, unless so recommended by the dimmer manufacturer. Doing so might shorten the life of the lamp and ballast.

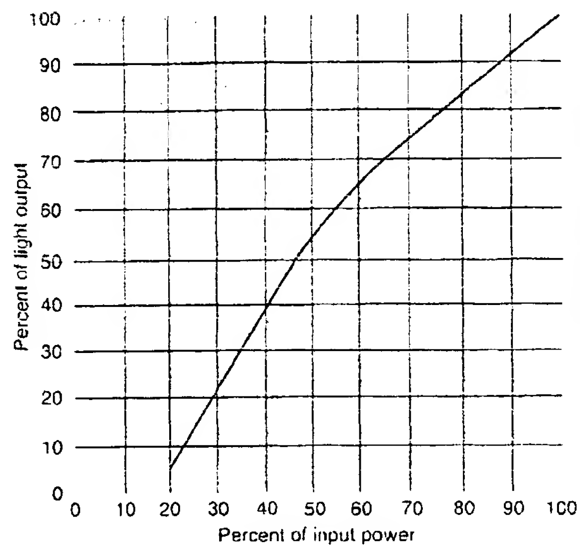


Figure 6-55. Light output vs. input power for a typical 40-watt 120-volt rapid-start fluorescent dimming system.

Flashing of Fluorescent Lamps.[46,47] Cold cathode and rapid-start or preheat-start hot cathode fluorescent lamps can be flashed and still maintain good performance. Cold cathode lamps are flashed through control of either the transformer primary or secondary voltage. Hot cathode lamps can be flashed by means of a special ballast that turns the arc current on and off but keeps the cathode heating on. An external flashing device is required with either system. This unit must be rated for the voltage and current involved and it is recommended that separate contacts be used for each ballast to prevent circulating currents between ballasts. Flashing of fluorescent lamps is sometimes used in advertising.

HIGH-INTENSITY DISCHARGE LAMPS

High-intensity discharge (HID) lamps include the groups of lamps commonly known as mercury, metal halide, and high-pressure sodium. The light-producing element of these lamp types is a wall-stabilized arc discharge contained within a refractory envelope (arc tube) with wall loading in excess of 3 W/cm² (19.4 W/in.²).

Lamp Construction and Operation

All high-intensity discharge lamps produce light by means of an electrical arc discharge contained in an arc tube inside the bulb. The arc tube contains tungsten electrodes that terminate the arc discharge at each end of the arc tube. The arc tube also contains a starting gas that is relatively easy to ionize at low pressure at normal ambient temperatures. This starting gas is usually argon or xenon or a mixture of argon, neon, or xenon, depending on the type of HID lamp. The arc tube also contains metals or halide compounds of metals that, when evaporated into the arc discharge, produce characteristic lines of radiant energy. Each type of HID lamp produces light related to the type of metal that is contained in the arc. Mercury vapor lamps produce light by exciting mercury atoms; high-pressure sodium lamps produce light by exciting sodium atoms; and metal halide lamps produce light by exciting several different atoms and molecules, primarily sodium, scandium, thulium, holmium, and dysprosium.

The arc tube is contained inside a soft or hard glass outer bulb to protect the arc tube and internal electrical connections from the environment. The outer bulb absorbs the majority of UV energy radiated by the arc tube while allowing light to pass through. The outer glass bulb can be coated with a diffusing material to reduce the source brightness of the lamp. In mercury vapor and metal halide lamps, this diffusing coating can be a color-correcting phosphor that uses UV energy radiated by the arc tube to improve the lamp's overall color rendering properties.

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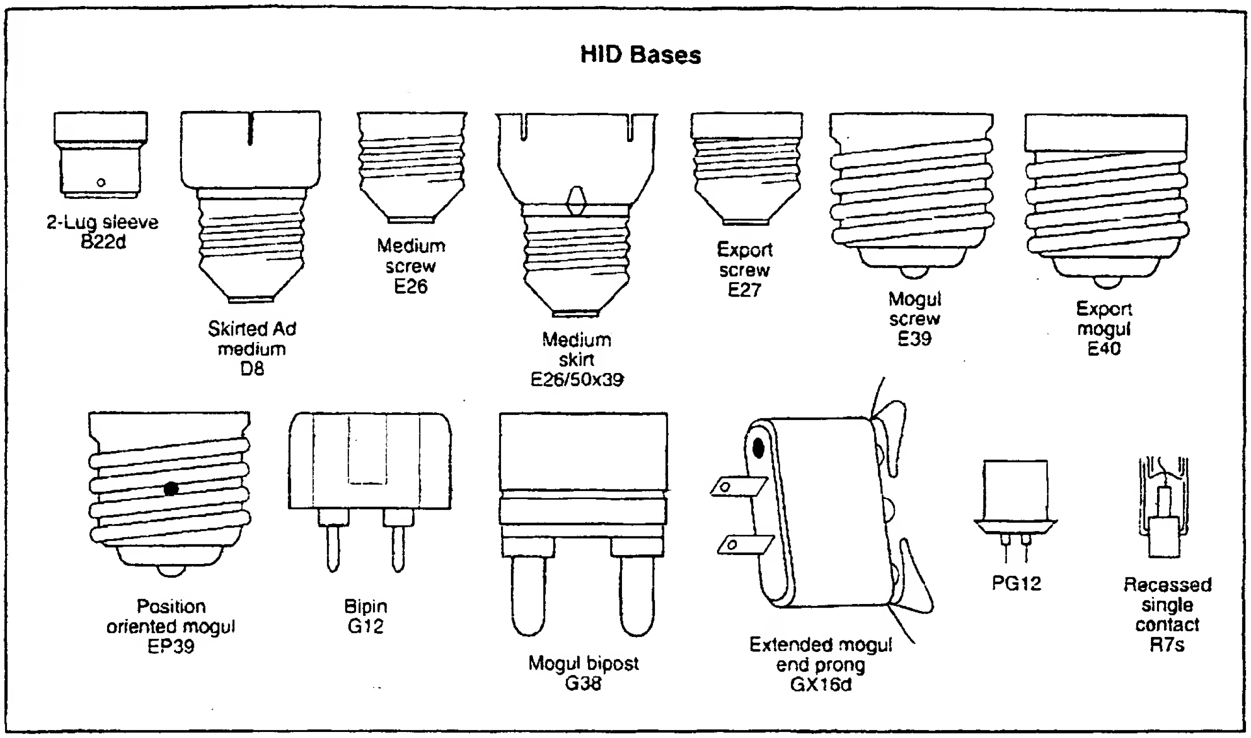

Figure 6-56. Common HID lamp bases (not to scale). ANSI designations are shown.

Within the outer bulb there are wires suitable for high temperatures to conduct electricity to the arc tube and structural components to support the arc tube. There might be other components, including resistors or diodes used to help start the arc discharge, and devices called getters to purify the atmosphere in the outer lamp. The atmosphere in the outer bulb might be a low-pressure gas (usually nitrogen) or, in many cases, a vacuum.

HID lamps have screw bases (medium or mogul) made from brass, nickel, or special alloys to minimize corrosion. Some HID lamps have special bipin bases or pairs of single contact bases at each end of the lamp to provide electrical connections (Figure 6-56).

If the outer bulb is broken and the arc tube continues to operate, the lamp emits a significant amount of UV energy. Exposure to people beyond about 15 minutes can produce severe erythemal effects (skin reddening) or eye damage (see Chapter 5, Nonvisual Effects of Optical Radiation, for more details). Self-extinguishing lamps usually contain a tungsten filament in place of a portion of nickel wire that will oxidize quickly and separate, extinguishing the electrical arc and turning the lamp off. The lamp is then inoperative and needs to be replaced.

Mercury Lamps.[48–52] In mercury lamps, light is produced by the passage of an electric current through mercury vapor. Since mercury has a low vapor pressure at room temperature, and even lower when it is cold, a small amount of more readily ionized argon gas is introduced to facilitate starting. The original arc is struck through the ionization of this argon. Once the arc strikes, its heat begins to vaporize the mercury, and this process continues until all of the mercury is evaporated. The amount of mercury in the lamp essentially determines the final operating pressure, which is 200 to 400 kPa (29 to 58 lb/in.^{2}) in the majority of lamps.

The electrodes of mercury lamps usually are made of tungsten, in which the emission material, composed of several metallic oxides, is embedded within the turns of a tungsten coil protected by an outer tungsten coil. The electrodes are heated to the proper electron-emissive temperature by bombardment energy received from the arc.

Most mercury lamps are constructed with two envelopes: an inner envelope (arc tube) that contains the arc, and an outer envelope that (1) shields the arc tube from outside drafts and changes in temperature; (2) usually contains a stable, low-pressure gas (generally nitrogen) that prevents oxidation of internal components and also increases the breakdown voltage across the outer bulb parts; (3) provides an inner surface that will accept phosphor coatings; and (4) normally acts as a filter, removing most of the UV radiation produced by the arc. Phosphors placed inside the outer envelope can convert some of this UV energy to light, as in fluorescent lamps.

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Typically, the mercury lamp's inner envelope (arc tube) is made of fused silica with thin molybdenum ribbons sealed into the ends as current conductors. The outer envelope (bulb) is usually made of hard (borosilicate) glass but also can be of other glasses for special transmission or where pollution and thermal shock are not problems.

The essential construction details shown in Figure 6-57 are typical of lamps with fused silica (quartz) inner arc tubes within an outer envelope. Other lamps, such as those for special photochemical application and self-ballasted types, have different constructions.

The pressure at which a mercury lamp operates accounts in large measure for its characteristic spectral power distribution. In general, higher operating pressure tends to shift a larger proportion of emitted radiation into longer wavelengths. At extremely high pressure there is also a tendency to spread the line spectrum into wider bands. Within the visible region the mercury spectrum consists of five principal lines (404.7, 435.8, 546.1, 577, and 579 nm), which result in greenish-blue light at efficacies of 30 to 65 lm/W, excluding ballast losses. While the light source itself appears to be bluish-white, there is a deficiency of long-wavelength radiation, especially in low- and medium-pressure lamps, and most objects appear to have distorted colors. Blue, green, and yellow are emphasized; orange and red appear brownish. Clear mercury lamps generally have a CRI value of approximately 15, and are not desirable for use where people will occupy the space. They are, however, quite suited to landscape lighting (see Chapter 21, Exterior Lighting).

A significant portion of the energy radiated by the mercury arc is in the UV region. Through the use of phosphor coatings on the inside surface of the outer envelope, some of this UV energy is converted to visible radiation. The most widely used lamps of this type are coated with a vanadate phosphor (4000 K, designation DX) that emits long-wavelength radiation (orange-red); this improves efficacy and color rendering. This phosphor also is blended with others to produce cooler or warmer colors. Figure 6-28 shows the spectral power distributions of a clear lamp and ones using these phosphors.

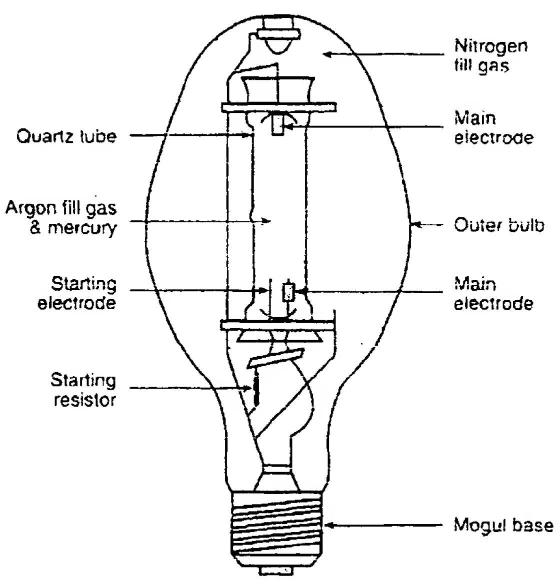

Figure 6-57. Mercury vapor lamp construction.

Metal Halide Lamps.[55-61] Metal halide lamps are similar in construction to mercury lamps, the major difference being that the metal halide arc tube contains various metal halides in addition to the mercury and argon. When the lamp attains full operating temperature, the metal halides in the arc tube are partially vaporized. When the halide vapors approach the high-temperature central core of the discharge, they are dissociated into the halogen and the metals, with the metals radiating their spectrum. As the halogen and metal atoms move near the cooler arc tube wall by diffusion and convection, they recombine, and the cycle repeats.

The use of metal halides inside the arc tube presents two advantages. First, metal halides are more volatile at arc tube operating temperatures than pure metals. This allows the introduction of metals with desirable emission properties into the arc at normal arc tube temperatures. Second, those metals that react chemically with the arc tube can be used in the form of a halide, which does not readily react with fused silica.

The efficacy of metal halide lamps is greatly improved over mercury lamps. Commercially available metal halide lamps have efficacies of 75 to 125 lumens/watt (excluding ballast losses). Almost all varieties of white-light metal halide lamps have color rendering properties as good as or superior to phosphor-coated mercury lamps.

The radiating metals introduced as halides in these lamps have characteristic emissions that are spectrally selective. Some metals principally produce visible radiation at a single wavelength, while others produce a multitude of discrete wavelengths. Still others provide a continuous spectrum of radiation. In order to obtain a desired spectrum, blends of metal halides are used. Two typical combinations of halides used are scandium and sodium iodides, and dysprosium, holmium, and thulium rare-earth (RE) iodides. Their spectral power distributions are shown in Figure 6-28. Other metals, such as tin, when introduced as halides, radiate as molecules, providing a continuous band spectra across the visible spectrum. The scandium-sodium system, for example, can produce CCTs between 2500 to 5000 K by varying the blend ratio and arc tube operating temperature. The rare-earth system, on the other hand, has a characteristic CCT of approximately 5400 K, which, when augmented by the inclusion of sodium iodide, may be lowered to 4300 K. A rare-earth system augmented with cesium and sodium iodides can achieve a CCT of 3000 K. The rare-earth system provides a somewhat higher general color rendering index than the scandium-sodium system; lithium iodide additions look

promising for enhancing the color rendering properties of the scandium-sodium system.

Selected colors also can be produced using single elements in the arc tube: sodium for orange, thallium for green, indium for blue, and iron for UV. Luminous efficacy and lamp life tend to be greater for scandium-sodium lamps, but thallium can be used to improve the efficacy of RE lamps. These trade-offs should be considered in selecting a lamp type for each particular application. Metal halide lamps are also available with phosphors applied to the outer envelopes (Figure 1-13). These phosphors lower the CCT of the lamps by approximately 300 K. The main use of the phosphor coating is to create a more diffuse light source.

Metal halide lamp construction is similar to that of a mercury lamp (Figure 6-58). One significant design characteristic is that the arc tubes usually are smaller for equivalent wattages. The metal halide arc tube has a white coating applied to the ends to increase vaporization of the metal halides.

Another design characteristic of metal halide lamps is that the arc tubes often are custom shaped. Most metal halide lamps are life- and lumen-rated in the vertical operating position. For instance, a universal operation lamp has its best performance in the vertical position. When a universal lamp is operated horizontally, the arc bows upward due to convection currents. At the same time, the metal halide pool (which is liquid) moves to the center of the arc tube. The bowed arc moves farther from the metal halides than when the lamp is vertical, causing them to cool. This lowers the vapor pressure of the metal halide chemicals and decreases the concentration of metals in the arc with a resulting loss in light. In addition, the bowed arc moves closer to the top of the arc tube wall, causing its temperature to increase. The higher wall loading on the arc tube material results in a decrease in life rating by approximately 25%.

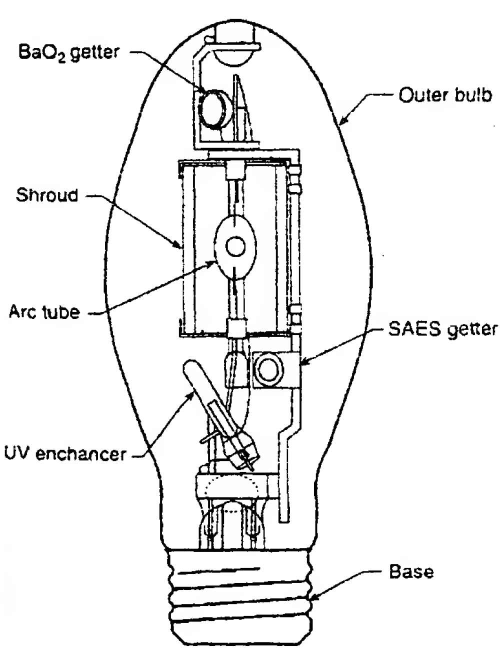

Figure 6-58. Metal halide lamp construction.

Since many applications require horizontal lamp orientation, a number of arc tube designs have been developed. There are two common configurations for horizontal high output arc tubes as shown in Figure 6-59. The first is a bowed arc tube shaped to follow the natural bowing of the horizontal arc. In this design, the chemicals are confined to the ends of the arc tube as the shape prevents migration. The second design is an asymmetric arc tube with the electrodes lower in the arc tube body such that the arc bows to the center line of the arc tube. Both of these designs provide increased light (approximately 25%) and longer life (approximately 33%) over the universal lamps operated horizontally.

Since the horizontal high-output arc tubes are designed to accommodate the upward bow of a horizontally operating arc, the arc tube must be operated horizontally to prevent overheating of the arc tube walls, which dramatically shortens lamp life and increases the probability of violent failures. A special base and socket are always used with horizontal high-output lamps to help ensure proper arc tube orientation (Figure 6-60). Lamp operating position is much less important for mercury and high-pressure sodium lamps.

Some arc tubes have been designed with ovoid shapes (Figure 6-61a). These arc tubes are actually formed in a mold using high-pressure gas. They are commonly referred to as formed body arc tubes. The older style of arc tubes are referred to as pinched body arc tubes (Figure 6-61b). The molding process ensures a highly repeatable and accurate shape for each arc tube. The actual contour and shape of the arc tube gives some excellent benefits in performance. The walls of the arc tube are contoured to better follow the shape of the arc, thereby allowing for a more uniform thermal profile for the arc tube. This shape also allows the metal halide chemicals to heat up more rapidly than those in the conventional pinched body arc tube. On average, formed body arc tubes warm up three times faster than pinched body arc tubes of the same wattage. Formed body arc tubes have much smaller pinch seal areas. These areas serve to cool the arc tube end chambers and thereby reduce lamp efficacy by lowering the temperature of the metal halide pool. This undesirable cooling is more of a problem in lower-wattage lamps in which the pinch seal area comprises a greater part of the total thermal mass of the arc tube than for the higher wattage lamps.

The smaller pinch seal area has an effect on lamp starting. The older pinch seal designs use a secondary starter electrode that helps to initiate breakdown of the arc tube gases. In formed body arc tubes, there is no room for the secondary electrode. Consequently the arc is initiated by a high-voltage pulse (typically 3,000 V minimum) applied directly across the main electrodes. Devices called ignitors are used to provide these starting pulses. Ignitor starting has

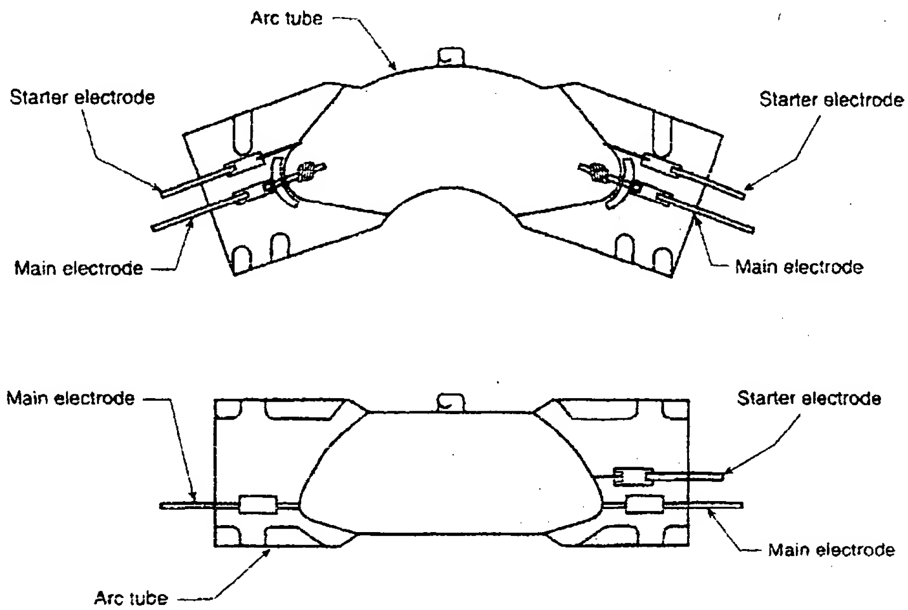

Figure 6-59. Common configurations for horizontal metal halide lamps.

been found to have additional performance features. In general, lamps start faster when ignitors are used. They start more reliably, and the fill pressure inside the arc tube can be increased over standard starter electrode systems. This higher fill pressure helps to retard tungsten evaporation from the electrode, which causes lumen depreciation due to arc tube wall darkening.

The classic pinched body metal halide lamps that use a starter electrode must also contain a system that provides for either shorting of the starter electrode to the main electrode or opening the starter electrode circuit after the lamps have started. This is required to prevent electrolysis in the fused silica between the starting and operating electrodes, especially when a halide such as sodium iodide is used in the lamp. Failure to short or open the starter electrode circuit will result in very short lamp lives. These starter circuits typically use a bimetal switch. The location and type of switch

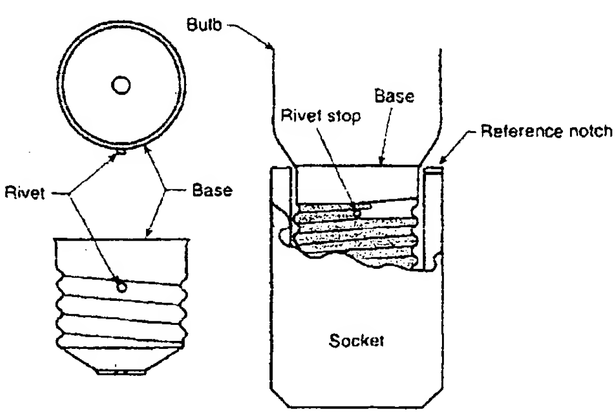

Figure 6-60. Base and socket configuration for some horizontal high-output metal halide lamps.

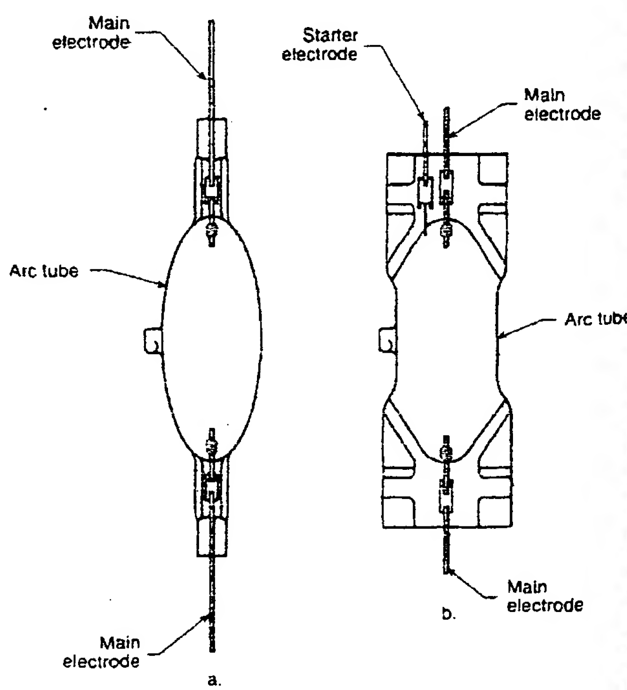

Figure 6-61. Common arc tubes: (a) ovoid, and (b) pinched body.

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can restrict the lamp operating position as the bimetal must achieve a certain temperature to function.

In some metal halide lamps the electrical connection to the electrode at the dome of the lamps is made by a small nonmagnetic wire remote from the arc tube. This prevents diffusion of sodium through the arc tube by electrolysis caused by a photoelectric effect when the current lead is near the arc tube. Most metal halide lamps above 150 W require a higher open-circuit voltage to start than mercury lamps of corresponding wattage. Therefore, they require specific ballasts. Certain metal halide lamps designs, however, can be operated on some types of mercury ballasts in retrofit situations.

Most metal halide lamps use getters to overcome impurities that, if present in the outer jacket of a metal halide lamp in sufficient concentrations, can compromise performance. The predominant problems arise from hydrogen and carbon contamination.

Special metal halide lamps are available that automatically extinguish the arc should the outer envelope break or puncture. They can be used in locations where exposure to UV radiation should be avoided.[62]

Low-wattage metal halide lamps[63-65] (below 175 W) come in many varieties for different applications, such as displays, recessed lighting, and track lighting. They produce brilliant white light in a small arc capsule enclosed in a small outer jacket. Such lamps include single-ended lamps with medium or E27 bases (32 to 175 W), single-ended lamps with bipin bases (35 to 150 W), and double-ended lamps with recessed single contact bases (70 to 150 W).

Some single-ended lamps use a transparent sleeve surrounding the arc tube called a shroud. A thin-walled shroud is useful as a heat shield because it helps achieve a more uniform arc tube temperature; it also retards sodium loss. A heavy shroud is used in lamps suitable for open luminaires. These shrouds prevent the outer jacket of the lamp from breaking in case of an arc tube violent failure. When relamping an open luminaire it is important to use only open luminaire rated lamps (those with shrouds). To prevent user misapplication the industry has developed unique socket and base combinations for both medium and mogul base lamps.

Certain metal halide lamps must be operated in enclosed luminaires designed to contain any hot quartz fragments that might result from an arc tube rupture. Some metal halide lamps do not have a hard glass outer jacket. These lamps can have either no outer jacket or an outer jacket that is made from fused silica that transmits UV energy. In these designs, the luminaire must have a cover glass providing the UV filtration.

High-Pressure Sodium Lamps.[66] In high-pressure sodium lamps, light is produced by electric current passing through sodium vapor. These lamps are constructed with two envelopes, the inner arc tube being polycrystalline alumina, which is resistant to sodium attack at high temperatures and has a high melting point. Although translucent, this material provides good light transmission (more than 90%). The construction of a typical high-pressure sodium lamp is shown in Figure 6-62.

Polycrystalline alumina cannot be fused to metal by melting the alumina without causing the material to crack. Therefore, an intermediate seal is used. Either solder, glass, or metal can be used. Ceramic plugs also can be used to form the intermediate seal. The arc tube contains both xenon as a starting gas and a small quantity of sodium-mercury amalgam, which is partially vaporized when the lamp attains

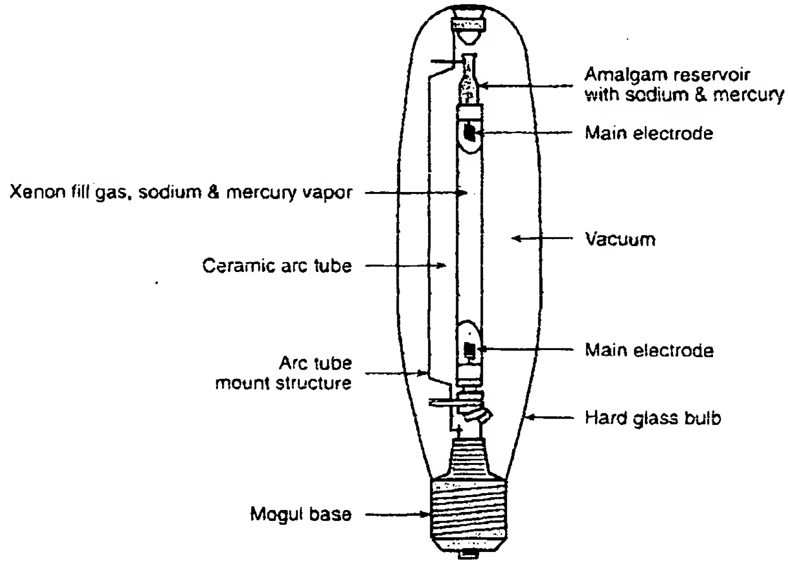

Figure 6-62. High-pressure sodium lamp construction.

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operating temperature. The mercury acts as a buffer gas to raise the gas pressure and operating voltage of the lamp.

The outer borosilicate glass envelope is evacuated and serves to prevent chemical attack of the arc tube metal parts. It also helps to maintain arc tube temperature by isolating the metal from ambient temperature effects and drafts.

Most high-pressure sodium lamps can operate in any position. The operating position has no significant effect on light output. Lamps are also available with diffuse coatings on the inside of the outer bulb to increase source luminous size or reduce source luminance.

High-pressure sodium lamps radiate energy across the visible spectrum. This is in contrast to low-pressure sodium lamps, which radiate principally the doublet D lines of sodium at 589 nm. Standard high-pressure sodium lamps, with sodium pressures in the 5 to 10 kPa (40 to 75 Torr) range, typically exhibit color temperatures of 1900 to 2200 K and have a CRI of 22. At higher sodium pressures, above approximately 27 kPa (200 Torr), sodium radiation of the D line is self-absorbed by the gas and is radiated as a continuous spectrum on both sides of the D line. This results in the dark region at 589 nm as shown in the typical spectrum in Figure 6-28. Increasing the sodium pressure increases the CRI to at least 65 at somewhat higher correlated color temperatures; however, life and efficacy are reduced. White high-pressure sodium lamps have been developed with correlated color temperatures of 2700 to 2800 K and a CRI between 70 and 80. Higher-frequency operation is one method of providing white light at reduced sodium pressure. High-pressure sodium lamps have efficacies of 45 to 150 lm/W, depending on the lamp wattage and desired color rendering properties.

Because of the small diameter of a high-pressure sodium lamp arc tube, no starting electrode is included as in the mercury lamp. Instead, a high-voltage, high-frequency pulse is provided by an ignitor to start these lamps. Some special high-pressure sodium lamps use a specific starting-gas mixture (a combination of argon and neon that requires a lower starting voltage than either gas alone) and a starting aid inside the outer bulb. These lamps can start and operate on many mercury lamp ballasts.

High-pressure sodium lamps are also available with two identical arc tubes contained within the outer bulb. These arc tubes are connected in parallel inside the lamp, but only one arc tube is started with the ignitor pulse. In the event of a momentary power outage, this dual arc tube lamp restrikes immediately when power is restored. Within about one minute, the lamp returns to full light output.

Lamp Designations

The current identifying designations of high-intensity discharge lamps generally follow a system that is authorized and administered by ANSI. All designations start with a letter (H for mercury, M for metal halide, S for high-pressure sodium). This is followed by an ANSI-assigned number that identifies the electrical characteristics of the lamp and ballast. After the number there are two letters that identify the size, shape, and finish of the bulb. After this sequence, the manufacturer may add special letters or numbers to indicate information not covered by the standard sequence of the designation, such as lamp wattage or color.

An example HID lamp designation is as follows:

M	57	PF	175/3K
(a)	(b)	(c)	(d)

(a) HID type. "S" is for HPS lamps, "M" is for MH lamps, and "H" is for mercury lamps.
(b) Electronic characteristics. For example, "57" is a 175-W MH lamp, "51" is a 400-W HPS lamp, "33" is a 400-W mercury lamp.
(c) Bulb characteristics. For example, "PF" is a phosphor-coated ED bulb, "PE" is a clear ED bulb.
(d) Additional characteristics. Many lamp manufacturers add additional (and often redundant) codes that more explicitly describe the wattage (175-W), color temperature (3000 K), or other special characteristics.

Lamp Starting

Mercury Lamps. Some special two-electrode mercury lamps, and many photochemical types, require a high open-circuit voltage to ionize the argon gas and permit the arc to strike. In the more common three-electrode lamps an auxiliary starting electrode placed near one of the main electrodes makes it possible to start the lamp at a lower voltage. Here, an electric field is first established between the starting electrode, which is connected to the opposite main electrode through a current limiting resistor, and the adjacent main electrode. This causes an emission of electrons, which develops a local glow discharge and ionizes the starting gas. The arc then starts between the main electrodes. The mercury gradually vaporizes from the heat of the arc and draws current. During this process the arc stream changes from the bluish glow of the argon arc to the blue-green of mercury, increasing greatly in luminance and becoming concentrated along the axis of the tube. At the instant the arc strikes, the lamp voltage is low. Normal operating values are reached after a warmup period of several minutes, during which the voltage rises until the arc attains a stabilization vapor pressure; the mercury is then entirely evaporated.

If the arc is extinguished, the lamp will not relight until it is cooled sufficiently to lower the vapor pressure to a point where the arc will restrike with the voltage available. The time from initial starting to full light output at ordinary room temperatures, with no enclosing lighting unit, and also the restriking time (the cooling time required before the lamp will restart), vary between 3 and 7 min, depending upon the lamp type.